Memorandum

To: Senate Bill 3 Science Advisory Committee (SAC)
From: Dan Opdyke, TPWD
Re: Flow Regime Application Tool (FRAT)
Date: January 13, 2012

Introduction

This memo serves as the primary documentation for the Flow Regime Application Tool (FRAT) and is current as of version 4.0.[1] FRAT was developed, as part of Senate Bill 3 efforts, to allow for the prediction of daily streamflows following the implementation of a proposed project (e.g., reservoir) that is required to pass inflow in accordance with a proposed environmental flow regime (eflow regime).[2] Accordingly, the model can be used to evaluate both the environmental protection afforded by the environmental flow regime and the firm yield and/or volume reliability of the proposed project. Although FRAT calculates firm yield and/or volume reliability estimates, it is important to recognize that such estimates will differ from those generated using the TCEQ's official WAM models and consequently may not conform with TCEQ regulatory requirements.

FRAT was originally developed by HDR Engineering, Inc. (HDR), has been substantially enhanced by the Texas Parks and Wildlife Department (TPWD), and is currently maintained by TPWD. It is available for download as part of the "HEFR-FRAT Toolset" from TCEQ: http://www.tceq.state.tx.us/permitting/water_supply/water_rights/eflows/resources.html. This model is an enhancement of the HDR-1 approach endorsed by the SAC in their November 12, 2010 report entitled "Consideration of Methods for Evaluating Interrelationships between Recommended SB-3 Environmental Flow Regimes and Proposed Water Supply Projects."

[1] Additional calculation details are provided in the FRAT spreadsheet itself.

[2] Such a task would ordinarily be accomplished using a Water Availability Model (WAM), however, the daily variable high flow pulse requirements cannot be directly input into the monthly WAMs.

Problem Statement and Overview

Senate Bill 3 Basin and Bay Expert Science Teams (BBEST) and Basin and Bay Area Stakeholder Committees (BBASC) have been charged with recommending eflow regimes. Thus far, these have taken the form of flow matrices, with seasonally-varying pass-through requirements for subsistence flows, base flows, and high flow pulses.[3] On their own, such flow matrices do not fully describe expected future flows in the river. Such information is often pivotal in evaluating the likelihood of maintaining a sound ecological environment, the yield of a new project, and/or an appropriate balance between these two. To generate expected future flows, FRAT combines pre-project flows with project characteristics, climatological information, an eflow matrix, and implementation rules.

FRAT consists of a daily water balance whereby flows are allocated to (1) downstream senior water rights, (2) evaporation, (3) eflow requirements, and (4) diversions and/or impoundments available to the proposed project. A typical application is shown in Figure 1.

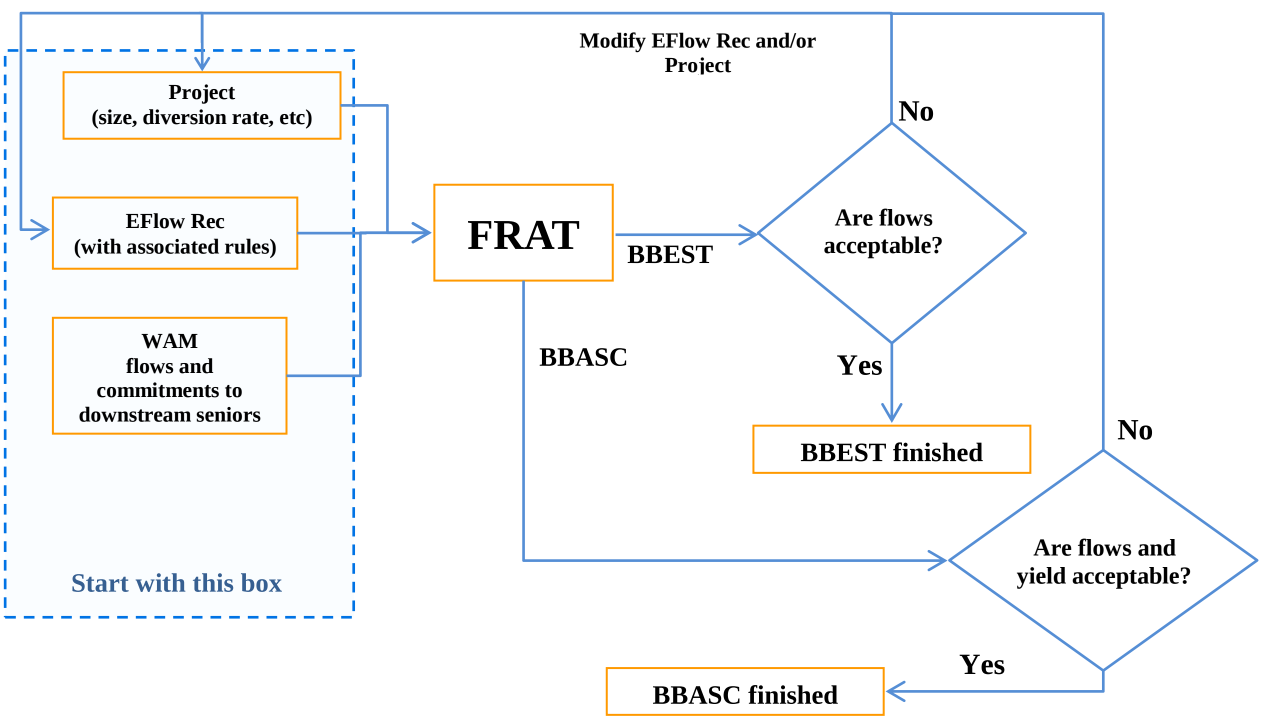

Figure 1. Typical Flow Chart for FRAT

[3] In this document, the term "high flow pulses" includes both high flow pulses and overbank events, as the distinction is irrelevant in FRAT.

Input Requirements

1. A daily flow record and flows obligated to downstream seniors

   This is often a monthly WAM output (i.e., regulated and unappropriated flows) that has been distributed to daily flows. FRAT does not perform the daily distribution; this is commonly accomplished using historical patterns (e.g., as discussed in the SAC document "Consideration of Methods for Evaluating Interrelationships between Recommended SB-3 Environmental Flow Regimes and Proposed Water Supply Projects"). The WAM run used (e.g., Run 3, Run 8, or regional planning) depends on the objectives of the analysis.

2. Project Characteristics

   - These may include reservoir volume, an elevation-area-volume table for reservoirs, run of river diversion rates, desired annual demand, monthly distribution of demands, available supplemental water supply, etc.

3. Climatological Characteristics

   - A time series of monthly hydrologic conditions and net evaporation rates.

4. EFlow Requirements

   - The eflow matrix being evaluated, including subsistence flows, base flows, and high flow pulses.

   - Implementation rules for the eflow matrix.

Assumptions and Limitations

1. If WAM outputs are used as inputs to FRAT, all assumptions and limitations of the WAM run are relevant to the FRAT outputs.

2. The project evaluated in FRAT must be the most junior water right in the basin and only one project, subject to one eflow measurement point, may be evaluated at a time.

3. The distribution of monthly WAM outputs to daily creates additional uncertainties.

4. Up to four seasons are allowed. These can be of any length.

5. The eflow measurement point is assumed to be located immediately downstream of the project.

6. FRAT has been set up to represent a variety of eflow implementation rules and includes significant flexibility. However, it cannot represent all possible implementation rules. Additional flexibility can be added, as needed. Lyons, Consensus Criteria, and 7Q2 are included, as are a variety of SB 3 proposed and adopted eflow implementation rules. Additional details can be found in the “instructions” sheet of FRAT.

7. The computation of compliance statistics for high flow pulses is not straightforward. FRAT provides two computational approaches. Additional approaches are possible. Additional details can be found below and in the “Compliance Stats” sheet in FRAT.

8. Three project types are possible: (1) on-channel reservoir, (2) off-channel reservoir, and (3) run-of-river diversion. Monthly distribution of demands is possible (similar to WAM Use Coefficients). Additional flexibility has been incorporated into FRAT to allow for more complex projects, such as conjunctive use type projects, though the use of the “supplemental water supply” input.

9. High flow pulses cannot occur on the first day of a season. Thus, the requirement to pass a high flow pulse that starts near the end of a season will be terminated at the end of the last day of the season, whereupon the algorithm reverts to base flow or subsistence flow. Credit for passage of the truncated high flow pulse is not given to either season. If flows remain high, a new high flow pulse may begin on day 2 of the new season.

10. Once the HFP volume or duration requirement is met, required passage of the high flow pulse is terminated and the subsequent day’s pass-through requirement is either the appropriate base flow or subsistence flow. If flows in the river remain high and additional HFP requirements have yet to be satisfied (e.g., the second event of the two per season requirement), then a new HFP can be triggered on the second day after termination of the first requirement.

11. Freshwater inflow requirements of any associated bay/estuary system are not included.

12. Previous versions of FRAT calculated compliance statistics for the various base flows and high flow pulses. These calculations are quite complex, subject to interpretation, and were not used by the BBESTs or BBASCs. For these reasons, compliance statistics were removed from version 4.0. Kirk Kennedy of Kennedy Resource Company generated a variety of different compliance statistics for the Colorado-Lavaca BBEST and BBASC, but those computations have not been incorporated into FRAT.

FRAT Contents

FRAT consists of a macro-enabled Excel spreadsheet that runs in Excel 2007 and 2010. It contains the following sheets:

1. Instructions

    - This sheet contains basic instructions.

    - This sheet also contains four buttons to run codes:

        - "Clear Old Dataset": This macro deletes all existing project data to restore a blank FRAT template for specification of a new project. Use this macro to start a building a new project.

        - "Copy Functions": This macro copies all necessary functions to the appropriate cells, depending on the number of days in your period of record. Use this macro after you have entered in all project information.

        - "Set y axis scale for freq curves": This macro sets a consistent y axis scale for all Flow Frequency Curves (FFCs) in FRAT.

        - "Update FFCs": Certain changes to a project (e.g., changes in delivery demand on a reservoir) do not require recreating a new FRAT simulation, but do change the streamflow results. Because the FFCs display a static (i.e., PasteSpecial Values) copy of the simulation results, this macro must be run after changing any project characteristics or other calculations so that the FFCs can be updated to display the correct information.

2. Model Options

    - This sheet contains user-input model options and metadata.

    - This sheet also contains model-calculated simulation characteristics (e.g., dimensions of the dataset).

3. Basic Data

    - This sheet contains user-input reservoir volume, storage-area-elevation information, hydrologic condition, net evaporation, streamflow, senior water right pass-through requirements, supplemental water supply (optional), and monthly use coefficients.

4. EFlow Matrix

    - This sheet contains the user-input environmental flow matrix and seasonal assignments.

5. HFP App

    - This sheet contains user-input tier (aka level) and return interval requirements for HFPs.

6. Calculations

- This sheet contains the bulk of the spreadsheet calculations, one row per day of the period of record.

- There is a target annual yield cell (aka delivery demand) that can be input by the user (one for reservoir projections and a separate cell for ROR diversion projects).

- If you wish to determine the firm yield of a reservoir project click the button labeled “Calculate Firm Yield” or simply manually change the Target Yield cell until the minimum volume is a small number (be sure to recalculate after every change). The “Calculate Firm Yield” code also allows the specification of a desired minimum storage (e.g., to correspond to a dead pool). The firm yield of an ROR project can be determined by setting the target yield to a high value and reading the minimum daily, monthly, and annual diversion values.

- The “Regulated Flow” column (in green) shows the final predicted streamflows. All cells to the right of this column are for accounting only.

7. Reliability

   - This sheet contains simple reliability statistics for simulations evaluating the overdrafting of projects (i.e., the imposed demand is greater than the firm yield and thus is not always reliable).

8. Graphic Data

   - This sheet contains sorted copies of the simulation outputs for plotting in the FFCs. It is important to remember that this sheet does not automatically update when project characteristics are changed. These numbers must be updated using the “Update FFCs” macro.

9. Graphic DataDOR

   - This sheet is identical to the Graphic Data sheet, except it only contains data from the drought of record.

10. Dry Year, Average Year, Wet Year

    - These three charts show the results for user-specified example years.

11. All Years

    - This sheet includes a set of button and drop-down boxes to assist the user in examining the simulation results over any period of interest.

12. Flow Freq Ann, Flow Freq Winter, Flow Freq Spring, Flow Freq Summer, Flow Freq Fall

- These charts include FFCs (aka flow duration curves) of the simulation outputs and data entered by the user.

13. Flow Freq AnnDOR, Flow Freq WinterDOR, Flow Freq SpringDOR, Flow Freq SummerDOR, Flow Freq FallDOR

    - These charts are identical to the non-DOR charts described above, except they only contain data from the drought of record.

14. EFlow WAM Format

    - This sheet contains the eflow passage requirements in a format suitable for use as input to a WAM.

15. Project Depletions WAM Format

    - This sheet contains the calculated volume of water that would be diverted or impounded for use by a potential project in a format suitable for input to a WAM.

16. AddData1, AddData2, AddData3, AddData4

    - These optional sheets may contain other datasets that the user wishes to include in the output charts. Common examples include flows from various WAM runs and historical (measured) flows.

17. AddData1DOR, AddData2 DOR, AddData3 DOR, AddData4 DOR

    - These optional sheets are identical to those above, except they should only contain data from the drought of record.

FRAT Usage in the Environmental Flows Process To-Date

<u>Sabine-Neches BBEST</u>

- Genesis of FRAT development to address effects of implementation of environmental flow regime recommendations on instream flows below an example on-channel reservoir project of a size reasonably expected within the SB1 regional planning horizon.

<u>Sabine-Neches BBASC</u>

- Limited, if any, use of FRAT.

<u>Trinity-San Jacinto BBEST</u>

- Limited, if any, use of FRAT.

Trinity-San Jacinto BBASC

- Limited, if any, use of FRAT.

Colorado-Lavaca BBEST

- Did not use FRAT, although BBEST recommended BBASC use FRAT to evaluate impacts of BBEST flow recommendations.

Colorado-Lavaca BBASC

- FRAT used extensively to help BBASC balance environmental flow needs and human water needs, including the following:
    - Reduction of water availability in the WAM as a result of imposition of CL BBEST flow recommendations imposed at select locations throughout the four basins.
    - Evaluation of a planned off-channel reservoir project and a hypothetical Aquifer Storage and Recovery (ASR) project, both subject to no eflow requirements, current eflow requirements (Lyons and Consensus), CL BBEST eflow recommendations, and modified CL BBEST eflow recommendations. Determined firm yield and post project daily instream flows for all representations of the projects. For off-channel project, used daily project depletions from FRAT as input to TCEQ WAM model to assess project's impacts on bay and estuary inflows.

Guadalupe-San Antonio BBEST

- Used for consideration of instream flows subject to alternative environmental flow regime recommendations considering large-scale example on-channel and off-channel reservoir projects.
- Provided instream flow time series for geomorphology overlay.

Guadalupe-San Antonio BBASC

- Used extensively for example project evaluations considering alternative environmental flow standard recommendations, firm yield, instream flows, instream habitat availability frequency, geomorphology, freshwater inflows to bays & estuaries, and cumulative effects of multiple projects.
- Flexibility and execution speed afforded opportunities for real-time alternative evaluations and decision making in BBASC meetings.

Nueces BBEST

- Used for consideration of instream flows subject to alternative environmental flow regime recommendations considering large-scale example on-channel and off-channel reservoir projects.
- Provided instream flow time series for geomorphology overlay and instream habitat availability frequency analyses.

Brazos BBEST

- Used for three on-channel reservoir sample project evaluations, including examination of streamflows and downstream mainstem sediment transport.